

Lynn C. Hadaway, MEd, RNC, CRNI

## Skin Flora and Infection

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### Abstract



*Human skin provides a great living environment for the growth of microbes. The types and numbers of microbes vary according to the part of the human body and the age and gender of the individual. These microbes have a definite impact on the incidence of catheter-related infections. By understanding the process of how infections develop, appropriate choices can be made for techniques and methods that prevent these infections.*

Catheter-related infections are a growing problem in the United States. Bloodstream infection (BSI) is now the 8th leading cause of death in the United States, with intravascular catheters causing the majority of these infections.<sup>1</sup> According to data collected through the National Nosocomial Infection Surveillance System (NNIS) at the Centers for Disease Control and Prevention (CDC), there are approximately 80,000 BSIs associated with central venous catheters occurring annually in US intensive care units. When the entire hospital is included, this number jumps to 250,000 annual cases. Mortality rates have been estimated as high as 35%, depending on the severity of illness, indicating that thousands of patients die annually from intravascular catheter use.<sup>2</sup> While these numbers seem alarming, they do not include infections limited to the insertion site, tunnel, or port pocket.

In 1880, Dr Louis Pasteur said “The germ is nothing. It is the terrain in which it is found that is everything.”<sup>3</sup> Because some part of the catheter system must pass through the skin, it is crucial to understand this terrain and the microorganisms living there, and their impact on catheter-related infections.

Lynn Hadaway has 30 years of experience in infusion therapy, including acute care clinical practice, continuing education/staff development, product manufacturing, and consulting practice. Currently, she is president of Lynn Hadaway Associates, Inc. a consulting company specializing in infusion therapy performance improvement.

Address correspondence to Lynn Hadaway, PO Box 10, Milner, GA 30257 (e-mail: [lynn@hadawayassociates.com](mailto:lynn@hadawayassociates.com)).

## • SKIN MICROORGANISMS

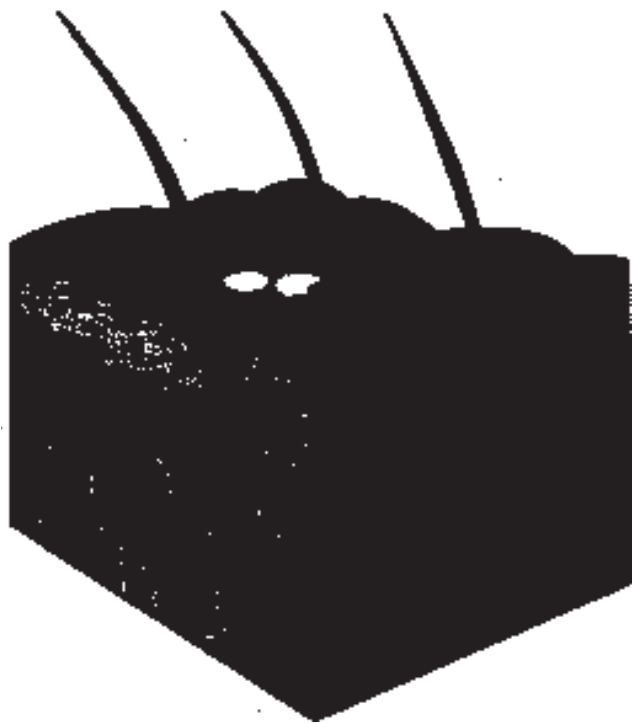


FIGURE 1.  
Structure of the skin.

## • NORMAL SKIN ANATOMY

Human skin is composed of two major sections, the epidermis and the dermis (Figure 1). The epidermis is actually five layers with cells in different stages of maturation. The dermis, the thickest layer, is composed of elastin and collagen fibers, sebaceous ducts, sweat glands, and hair follicles. Microorganisms are found in all layers of skin, not just the skin surface. Microbes reside in the hair follicles where they are protected from antiseptics by lipids at the opening of the follicle.<sup>4</sup> Antiseptics do not penetrate into the sebaceous ducts. It has been estimated that skin preparation procedures leave approximately 20% of the resident skin flora.<sup>5</sup>

There are three different types of human skin, each with a different profile of microorganisms—wet, dry, and oily.<sup>6</sup> The skin of the axilla and groin is wet with the highest numbers and types of microbes. The skin of the extremities is dry with the fewest number and types of microbes. This is one explanation for the low rates of catheter-related infections in midline and peripherally inserted central catheters.<sup>7</sup> Oily skin rich in sebum is found on the forehead, neck, and upper chest. Catheters placed in the jugular vein are reported to have a rate of infection higher than the subclavian insertion site, probably because of the density of skin flora.<sup>8</sup>

Transient flora is found on the skin surface and can include any microorganism, including virulent pathogens such as methicillin-resistant *Staphylococcus aureus* and the *Candida* species. Resident flora is found within the layers of skin and glands. As these skin layers mature and cells move to the surface, the microorganisms also rise to the surface. Resident flora includes coryneforms, staphylococci, *Acinetobacter*, micrococci, and *Malassezia*.

Coryneform bacteria are a large group of organisms, commonly known as diphtheroids. They are aerobic and found in small colonies as a universal inhabitant of human skin. Although frequently identified as a contaminant of blood cultures, this group has been reported to cause bacteremia and endocarditis.<sup>9</sup>

Many of the staphylococci species are found on human skin. On the head and thorax, *Staphylococcus epidermidis* is the dominant species and *Staphylococcus hominis* is more prevalent on the arms and legs. The term *S epidermidis* often is used interchangeably with coagulase-negative staphylococci (CNS). There are more than 30 species of CNS; *S epidermidis* is only one.<sup>9</sup> Studies of skin specimens taken after surgical scrubbing prior to spinal surgery yielded 14 strains of staphylococci.<sup>4</sup> Another study of preoperative skin cultures taken from the pectoral region before pacemaker insertion found 88% were positive for bacterial growth and 85% of the cultured organisms were staphylococci.<sup>10</sup> According to NNIS data from the CDC, the most common pathogen in bloodstream infections for the past 15 years has been CNS. *Enterococcus* species now hold second place followed by *S aureus* as the most prevalent pathogen.<sup>2</sup>

*Acinetobacter* is gram-negative bacteria found extensively in many areas of nature such as soil and water. Approximately 25% of the human population has skin colonization of this bacterium. *Acinetobacter* rarely causes community-acquired infection. Nosocomial bacteremia is primarily associated with a pulmonary source but also can be associated with intravascular catheters.<sup>9</sup> Skin colonization of micrococci is more common in women and children. This bacteria rarely causes disease, therefore there is very little research about it.

*Malassezia furfur* is found in skin as yeast and can be cultured from 97% of human subjects. The greatest number of colonies can be found on the scalp, forehead, and trunk of the body with smaller numbers on the extremities. Prevalence of this organism is rare in newborns, increases during childhood and adolescence, and decreases in elderly people. Its presence is directly related to the amount of sebum produced in the skin.<sup>11</sup>

Many factors affect the growth of organisms in and on the skin. Nutrients such as amino acids, sugars, vitamins, and electrolytes are found on human skin; how-

ever, there is little known about the specific nutrients needed to support microorganism growth. There are great differences in the composition of human sweat and laboratory situations cannot easily duplicate these differences. Lipids in the skin are composed of triglycerides, wax, cholesterol, and free fatty acids. The total impact of these lipids is unclear, although lipids inhibit the growth of *S aureus* and removing lipids with alcohol increases the microbes' survival time. Microorganisms adhere to the skin, although we don't understand exactly how this occurs. Humidity at the skin surface causes a rapid, dense growth of microbes.

Skin microorganisms have been studied in different groups of people. Skin cultures of people seen in an outpatient setting revealed greater numbers of micrococci and more prevalence of methicillin-sensitive *S aureus*. Microorganisms cultured from the skin of hospitalized patients are influenced by their disease and nutritional status.

Staphylococci are more prevalent than micrococci. Skin moisture due to occlusive dressings and plastic impermeable mattress covers are contributing factors to this growth of staphylococcus. Methicillin-resistant *S aureus* is more prevalent in hospitalized patients due to antibiotic use and the problem of emerging antibiotic resistance. Gram-negative bacteria also increase with prolonged hospital stays.<sup>12</sup>

There are gender-related differences in the amount of bacteria found on the skin. Men have greater numbers of skin flora with more cells per colony. Women have smaller number of skin flora with fewer cells in each colony. Age also produces skin flora differences. The neonate moves from the sterile uterus to become colonized with *S epidermidis* within days after delivery. Aging causes a decrease in active sweat and sebaceous glands. Aging skin may appear dry but it will actually have higher water content. Yeast can be cultured more often from the skin of older people.<sup>12</sup>

Skin cultures of healthcare workers are affected by frequent handwashing and subsequent irritant contact dermatitis. Frequent washing and glove use causes epidermal water loss and leaching of lipids. Damaged hands are more likely to be colonized with *S aureus*, gram-negative bacteria, enterococci, and yeast.<sup>13</sup>

## • CATHETER-RELATED INFECTIONS

Microorganisms causing catheter-related bloodstream infections come primarily from two sources—the patient's skin and the catheter hub. When the signs and symptoms of infection develop within the first week of catheter dwell, the skin is considered to be the source, whereas infections occurring after the first week of catheter dwell are attributed to introduction of microor-

ganisms through the catheter hub.<sup>14-17</sup> Infection is a result of complex interactions between the catheter surface, the microbes and their formation of biofilm, and the rich resource of plasma proteins.

Biofilm can be found in all aquatic systems from nature, industrial and household environments. The slimy substance found in a pet's water dish or a child's swimming pool is biofilm. Biofilm is "a structured community of bacterial cells enclosed in a self-protected polymeric matrix within which the bacteria metabolically cooperate to protect themselves in a hostile environment."<sup>7(p15)</sup>

A well-published and widely held belief is that microbes migrate from the skin down the catheter surface, colonize the catheter, and cause bloodstream infection. New research is pointing to a different concept—that bacteria firmly attach to the catheter's external surface as it passes through the skin on insertion. Infection occurs when this bacteria has produced enough biofilm to break away and move to other sites.<sup>7</sup>

Immediately after insertion, plasma proteins begin to attach to the catheter. Within 5 minutes, the layer of proteins adhered to the catheter surface and the proteins in the bloodstream have equalized. The coagulation cascade is set in motion, with platelets and white blood cells also adhering to the catheter surface. Within a few hours, fibrin has formed along the catheter. Depending upon the patient's coagulation factors, a peri-catheter thrombus may form on top of the fibrin sheath within days.<sup>7</sup>

In addition to microbes introduced when the catheter enters the bloodstream, other microbes may be free-floating in the bloodstream or flushed in through the catheter lumen. These floating or planktonic microbes interact with the platelet-protein layer on the catheter. Bacteria such as *S epidermidis*, *S aureus*, and fungi easily bind to this protein layer by producing adhesive substances. They interact with platelets to firmly attach to the catheter surface. The microbes also produce a slimy substance loosely attached to the cell surface. Biofilm cells can naturally detach and move to other sites for attachment. Shearing forces produced by blood flow or catheter flushing can cause the detachment of biofilm cells.<sup>7</sup>

Biofilm will always be present on intravascular catheters; however, infection occurs when the number of organisms exceed a certain level. The free-floating bacteria that have naturally detached or have been sheared off are responsible for producing the acute febrile episode and BSI. The bacterial shower released from the intraluminal biofilm causes symptoms only when the catheter is flushed.<sup>7</sup>

Biofilm is resistant to host defense mechanisms of the immune system. Antibiotics do not penetrate into the deep layers of biofilm, although they are effective against the free-floating cells. Short of removing the catheter, there is no way to remove the biofilm from the catheter surfaces.

The most common method for diagnosing a catheter-related BSI is to remove the suspected catheter and culture the catheter tip. This method sacrifices the catheter, requiring that another device be inserted to continue infusion therapy. Blood cultures taken from the catheter lumen also can be compared to blood cultures drawn from a peripheral venipuncture. A growth of five times more colonies from the catheter confirms catheter-related BSI.

A new endoluminal brush (FAS Endoluminal Brush, FAS Medical International, Middlesex, England) recently introduced to the US market may offer a unique way to obtain a sample of the biofilm for culturing. The device consists of movable bristles attached to a long wire. As it passes through the catheter lumen, the bristles flatten. When the brush is withdrawn from the catheter lumen, the bristles reverse direction and collect the debris along the catheter wall. British studies have shown this method to be successful to correctly diagnosis catheter-related infection and to be more sensitive than the catheter culture techniques currently being used.<sup>18</sup>

## ● PREVENTING CATHETER-RELATED INFECTIONS

Prevention of catheter-related infections results from meeting two main goals: reducing the development of fibrin and thrombus problems and minimizing the amount of microorganisms that are introduced to the catheter. Methods also can be divided into groups that prevent infection from the skin versus methods that reduce introduction through the catheter hub (Table 1).

Prophylactic anticoagulation with warfarin 1 or 2 mg daily has been shown to reduce the incidence of catheter-related thrombosis.<sup>19,20</sup> Intraluminal thrombolysis can be accomplished with instillation of thrombolytic agents, possibly enhancing the effectiveness of

antibiotics. More studies are required for specific recommendations for this treatment.<sup>7</sup>

Methods to reduce the introduction of microorganisms begin with the use of antiseptics. Chlorhexidine gluconate is now the skin antiseptic agent most commonly recommended for catheter insertion and routine catheter care.<sup>21,22</sup> Repeated use enhances the effectiveness because the chlorhexidine binds with skin cells to prolong the microbicidal activity. The current formulation is a combination of chlorhexidine gluconate and isopropyl alcohol. As indicated in the instructions for use of specific brands, catheters made of some polyurethane material may not tolerate alcohol well.<sup>23</sup> When cleaning the skin around the insertion site, clinicians should not clean the catheter with alcoholic solutions and should ensure that the solution is thoroughly dry before covering the catheter with the dressing. If using polyurethane catheters clinicians should read the manufacturer instructions for use found in each catheter package. Statements about alcohol use usually are found in the section on “Cautions” or “Warnings.”

Maximal barriers during the insertion procedure include use of sterile gown, caps, masks, and large sheet drapes. Catheters with antimicrobial coatings are strongly recommended when short-term therapy is required.<sup>2,22</sup> These coatings are made of combinations of chlorhexidine and silver sulfadiazine or minocycline and rifampin. Nontunneled percutaneous central catheters intended for short-term use are available with these coatings. Peripherally inserted central catheters, tunneled catheters, and implanted ports are not available with these coatings yet.

Hand care for healthcare professionals must receive adequate attention. Choices for hand hygiene are washing with soaps commonly containing chlorhexidine gluconate and the use of waterless alcoholic hand gels. These gels contain emollients to prevent skin irritation and are equally as effective as handwashing. Skin moisturizing requires careful choices. Many times, nurses

**TABLE 1**

**Preventing Catheter-related Infections**

<b>From the Patient's Skin</b>	<b>From the Catheter Hub</b>
Skin antiseptics with chlorhexidine gluconate	Hand hygiene for caregivers
Site care with chlorhexidine gluconate	Extending the life of administration sets used for continuous infusion
Careful attention to sterile technique during insertion	Careful attention to clean, no-touch technique when handling all catheter connections
Maximum barriers during insertion	Avoid use of stopcocks
Using catheters with antimicrobial coatings	Cleaning catheter hub surfaces when changing administration sets or injection caps
Subcutaneous tunnels	Cleaning injection surfaces before use
Subcutaneous cuffs around the catheter	Changing fluid container and administration set simultaneously

will bring a favorite lotion from home because lotions found in the hospital are intended for patient use and are inadequate for nurse's hands. Some lotions will destroy the antimicrobial activity of the chlorhexidine in the soap.<sup>13</sup> Also some lotions will degrade latex, increasing skin irritation by transferring latex proteins from the glove to the skin.<sup>13</sup>

Introduction of intraluminal microorganisms occurs each time the hub is manipulated during tubing or injection port changes, flushing procedures, and withdrawing blood samples. Skin flora from a clinician performing these procedures can be shed into the hub and flushed intraluminally. Activities to reduce the number of times the catheter hub is entered include extending the life of administration sets, careful handwashing prior to hub manipulation, and thorough cleaning of all hub surfaces and injection ports.

Finally, the impact of the infusion nurse's role in product selection, patient care, and administration is of great importance. The CDC has recommended specialized teams of nurses to insert and maintain catheters for many years and now carries their highest level of recommendation.<sup>2</sup> Specialized knowledge and skill are useful when selecting infusion products, and characteristics of catheters, antiseptics, and dressings must be chosen to work well together. Infusion nurses also fill a consultative role by recommending the most appropriate catheter to meet the specific needs of each patient. Education and training are required to ensure that all staff have the appropriate knowledge and skill to care for patients with catheters. Outcome monitoring is critical to complete the entire program. Catheter outcomes must be routinely tracked and an improvement plan created. Staff competency assessment programs should be planned in conjunction with the challenges identified through outcome monitoring.

## • CONCLUSION

Catheter-related BSI presents a definite challenge and excessive burden on our current healthcare system, costing billions of dollars each year. Each facility must know their specific outcomes and investigate methods to decrease the incidence of catheter-related infections.

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